Liquid Propellant Rocket Engines

Liquid propellants

Monopropellants

(capable of igniting or exothermic decomposition)

Ex: Hydrazine (N_2H_4)

Bipropellants

- $O_2 - H_2$
- $O_2 - RP1$
- $N_2O_4 - MMH\ [CH_3NHNH_2]$
- $N_2O_4 - UDMH\ [(CH_3)_2NNH_2]$

Desirable propellant characteristics (from Sutton, "Rocket Propulsion Elements.")

1. Low freezing point
2. High specific gravity ($SG = \frac{\rho}{\rho_{H_2O}}$)
3. Stability
4. high specific heat, high thermal conductivity, and high boiling point for propellants used for cooling
5. Low vapor pressure is a desirable pumping characteristic
6. Variation of physical properties with temperature should be small and/or similar for fuel and oxidizer.
7. readily ignitable

Oxidizer-fuel mass ratio (r): (aka mixture ratio)

$$r \overset{def}{=} \frac{\dot{m}_{ox}}{\dot{m}_F} = \frac{\dot{n}_{ox}\bar{M}_{ox}}{\dot{n}_F\bar{M}_F}$$

Average bulk density (ρ_{bulk})

$$\rho_{bulk} \overset{def}{=} \frac{m_f + m_{ox}}{\forall_f + \forall_{ox}} = \frac{m_f\left(1 + \frac{m_{ox}}{m_f}\right)}{\frac{m_f}{\rho_f} + \frac{m_{ox}}{\rho_{ox}}}$$

$$\rho_{bulk} = \frac{(1+r)\rho_f \rho_{ox}}{\rho_{ox} + r\rho_f}$$

LOX – LH_2 rocket : $r = 4$, $SG_{LOX} = 1.14$, $SG_{LH_2} = 0.071$

$\rho_{LOX} = 1140\ kg/m^3$, $\rho_{LH_2} = 71\ kg/m^3$ $\left(\rho_{H_2O} = 1000\ kg/m^3\right)$

$$\rho_{bulk} = \frac{(1+4)(71)(1140)}{1140 + (4)(71)} = 284\ kg/m^3$$

LOX – RP1 (kerosene) rocket: $r = 2.58$, $SG_{RP1} = 0.815$

$\rho_{RP1} = 815\ kg/m^3$

$$\rho_{bulk} = \frac{(1+2.58)(815)(1140)}{1140 + (2.58)(815)} = 1026\ kg/m^3$$

For a given propellant mass,

$$\forall_{tank\ (LOX/LH_2)} \simeq 3.6\ \forall_{tank\ (LOX/RP1)}$$

[Study Table 12-1]